CLAIMS

What is claimed is:

1. A method for quantifying the operation of a recovery boiler burning black liquor fuel bearing sodium compounds through knowledge of when its heat exchanger leaks working fluid into the combustion gas path producing a tube leakage, the method for quantifying the operation comprising the steps of:

monitoring the recovery boiler burning black liquor fuel bearing sodium compounds by one of the Input/Loss methods,

developing a mathematical model of the combustion process incorporating terms commonly associated with black liquor fuel combustion including sodium compounds and terms associated with sources of working fluid flows into the combustion gas path including tube leakage resulting in a stoichiometric model of the combustion process, and

determining a tube leakage in moles based on the stoichiometric model of the combustion process.

2. The method according to claim 1 further comprising the steps, after determining, of:

obtaining a molecular weight of the fossil fuel,

obtaining a molecular weight of the working fluid,

obtaining a fuel flow rate of the recovery boiler,

determining a tube leakage mass flow rate based on the tube leakage in moles, the molecular weight of the fossil fuel, the molecular weight of the working fluid, the fuel flow rate, and the stoichiometric model of the combustion process, and

reporting the tube leakage mass flow rate such that corrective action may take place.

3. The method of claim 1, wherein the step of determining the tube leakage in moles comprises the steps of:

forming a hydrogen stoichiometric balance based on the stoichiometric model of the combustion process using a molar base, and

solving the hydrogen stoichiometric balance for the tube leakage in moles.

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4. The method according to claim 2 further comprising the steps, after reporting, of:

identifying a set of heat exchangers descriptive of the recovery boiler as employed to transfer net energy flow to the working fluid from the combustion gases resulting in a set of identified heat exchangers,

obtaining a set of Operating Parameters applicable to the set of identified heat exchangers,

analyzing a set of net energy flows to the working fluid from the combustion gases based on the set of identified heat exchangers, the set of Operating Parameters and the tube leakage flow rate, each analyzed set descriptive of the recovery boiler and wherein each analyzed set the tube leakage flow rate is assigned to a different heat exchanger, resulting in an analyzed set of heat exchangers,

determining a reference key comparative parameter for the recovery boiler,

obtaining a set of key comparative parameters associated with each identified heat exchanger, applicable with the reference key comparative parameter, and based on the analyzed set of heat exchangers,

determining a set of deviations between the set of key comparative parameters and the reference key comparative parameter,

determining an identification of the leaking heat exchanger based on the set of deviations, and

reporting to the operator of the recovery boiler the identification of the leaking heat exchanger such that corrective action may take place.

5. A method for quantifying the operation of a recovery boiler burning black liquor fuel bearing sodium compounds when being monitored by one of the Input/Loss methods through knowledge of when its heat exchanger leaks working fluid into the combustion gas path producing a tube leakage, the method for quantifying the operation comprising the steps of:

developing a mathematical model of the combustion process incorporating terms commonly associated with the combustion of black liquor fuel including sodium compounds and terms associated with sources of working fluid flows into the combustion gas path including tube leakage resulting in a stoichiometric model of the combustion process,

selecting a set of minimization techniques applicable to the recovery boiler burning black liquor fuel, and a set of routine inputs and convergence criteria to the minimization techniques,

selecting a Choice Operating Parameter of tube leakage flow rate,

selecting a set of routine Choice Operating Parameters,

determining a set of System Effect Parameters applicable to the recovery boiler burning black liquor fuel whose functionalities are sensitive to tube leakage flow rate,

determining a set of Reference System Effect Parameters applicable to the set of System Effect Parameters,

determining an objective function applicable to the recovery boiler's stoichiometric situation which uses the Choice Operating Parameter of tube leakage flow rate, the set of routine Choice Operating Parameters, the set of System Effect Parameters, and the set of Reference System Effect Parameters,

optimizing the Choice Operating Parameter of tube leakage flow rate and the set of routine Choice Operating Parameters based on the mathematical model of the combustion process, the set of minimization techniques and the objective function such that convergence criteria is met resulting in a set of converged Choice Operating Parameters including the tube leakage flow rate, and

reporting the tube leakage flow rate such that corrective action may take place.

6. The method according to claim 5 further comprising the steps, after reporting, of:

determining a set of Reference Fuel Characteristics,

determining the fuel chemistry of the black liquor fuel being combusted in the recovery boiler using one of the Input/Loss methods, the mathematical model of the combustion process, the set of converged Choice Operating Parameters, and the set of Reference Fuel Characteristics,

determining a fuel heating value of the system based on the fuel chemistry and the set of Reference Fuel Characteristics,

obtaining a set of Operating Parameters,

determining a Firing Correction base on the set of Operating Parameters, and

determining a high accuracy boiler efficiency of the recovery boiler independent of fuel flow based on the set of converged Choice Operating Parameters including the tube leakage flow rate, the fuel chemistry, the fuel heating value, the Firing Correction and the set of Operating Parameters.

7. The method according to claim 6 further comprising the steps, after determining the high accuracy boiler efficiency, of:

determining an energy flow to the working fluid of the recovery boiler based on the set of Operating Parameters as influenced by the tube leakage flow rate,

determining a fuel flow of the fossil fuel being combusted using the energy flow to the working fluid, the fuel heating value, the Firing Correction and the high accuracy boiler efficiency, and

reporting the fuel flow as influenced by the tube leakage flow rate.

8. The method according to claim 7 further comprising the steps, after reporting, of:

determining a useful output from the recovery boiler,

determining a system efficiency using the fuel flow, the fuel heating value, the Firing Correction and the useful output from the recovery boiler, and

reporting the system efficiency as influenced by the tube leakage flow rate.

9. The method according to claim 7 further comprising the steps, after reporting, of:

determining a useful output from the recovery boiler,

determining a system efficiency using the energy flow to the working fluid, the high accuracy boiler efficiency and the useful output from the recovery boiler, and

reporting the system efficiency as influenced by the tube leakage flow rate.

10. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a BFGS technique applicable to the recovery boiler and its fuel.

11. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a Simulated Annealing technique applicable to the recovery boiler and its fuel.

12. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a neural network technique applicable to the recovery boiler burning black liquor fuel.

13. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a Neugents technology applicable to the recovery boiler burning black liquor fuel.

14. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a Pegasus Technology applicable to the recovery boiler burning black liquor fuel.

15. The method of claim 5, wherein the step of selecting the set of minimization techniques applicable to the recovery boiler burning black liquor fuel comprises a step of:

incorporating a NeuCo, Inc. technology.

16. The method of claim 5, wherein the step of selecting the set of routine Choice Operating Parameters comprises a step of:

determining a set of scaling factors for the set of routine Choice Operating Parameters resulting in the set of routine Choice Operating Parameters whose values are scaled.

17. A method for quantifying the operation of a recovery boiler burning black liquor fuel when being monitored on-line by The Input/Loss Method through knowledge of when its heat exchanger leaks working fluid into the combustion gas path producing a tube leakage flow rate, the method comprising the steps of:

before on-line operation,

developing a mathematical model of the combustion process incorporating terms commonly associated with the combustion of black liquor fuel and terms associated with sources of working fluid flows into the combustion gas path including tube leakage resulting in a stoichiometric model of the combustion process, and

selecting a set of minimization techniques applicable to the recovery boiler burning black liquor fuel, and a set of routine inputs and convergence criteria to the minimization techniques; and thereafter

performing a Pass 0 monitoring cycle while operating on-line which determines a trip mechanism associated with a tube leakage flow rate, comprising the steps of:

assuming a tube leakage flow rate is zero,

selecting a set of routine Choice Operating Parameters,

determining a set of System Effect Parameters applicable to the recovery boiler burning black liquor fuel whose functionalities effect the determination of system efficiency, and determining applicable Reference System Effect Parameters,

performing a Pass 0 monitoring cycle using The Input/Loss Method resulting in a set of fuel concentrations and correction factors to the set of routine Choice Operating Parameters,

testing the set of fuel concentrations and correction factors against a set of corresponding limits resulting in a trip mechanism indicating the stoichiometric reason how a heat exchanger may leak a tube leakage flow rate into the combustion gas path, and

assuming the trip mechanism indicates a tube leakage flow rate is possible; and thereafter

performing a Pass 1 monitoring cycle while operating on-line which determines a tube leakage flow rate, comprising the steps of:

multiplying a value of uncorrected effluent water concentration by a reference correction factor resulting in a constant effluent water concentration,

multiplying a value of uncorrected effluent carbon dioxide concentration by a reference correction factor resulting in a constant effluent carbon dioxide concentration,

selecting a set of routine Choice Operating Parameters including tube leakage flow rate but excluding effluent water and carbon dioxide,

determining a set of System Effect Parameters applicable to the recovery boiler burning black liquor fuel whose functionalities effect the determination of system efficiency and are sensitive to tube leakage flow rate, and determining applicable Reference System Effect Parameters,

performing a Pass 1 monitoring cycle using The Input/Loss Method resulting in a set of converged Choice Operating Parameters including the tube leakage flow rate, and thereafter;

reporting the tube leakage flow rate such that corrective action may take place.

18. The method according to claim 5 further comprising the steps, after reporting, of:

identifying a set of heat exchangers descriptive of the recovery boiler as employed to transfer net energy flow to the working fluid from the combustion gases resulting in a set of identified heat exchangers,

obtaining a set of Operating Parameters applicable to the set of identified heat exchangers,

analyzing a set of net energy flows to the working fluid from the combustion gases based on the set of identified heat exchangers, the set of Operating Parameters and the tube leakage flow rate, each analyzed set descriptive of the recovery boiler and wherein each analyzed set the tube leakage flow rate is assigned to a different heat exchanger, resulting in an analyzed set of heat exchangers,

determining a reference key comparative parameter for the recovery boiler,

obtaining a set of key comparative parameters associated with each identified heat exchanger, applicable with the reference key comparative parameter, and based on the analyzed set of heat exchangers,

determining a set of deviations between the set of key comparative parameters and the reference key comparative parameter,

determining an identification of the leaking heat exchanger based on the set of deviations, and

reporting to the operator of the recovery boiler the identification of the leaking heat exchanger such that corrective action may take place.

19. The method of claim 18, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a fuel flow as the reference key comparative parameter for the recovery boiler.

20. The method of claim 18, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a fuel water fraction as the reference key comparative parameter.

21. The method of claim 18, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a heating value as the reference key comparative parameter.

22. The method of claim 18, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a Fuel Consumption Index for each heat exchanger as the reference key comparative parameter for the recovery boiler.

23. A method for quantifying the operation of a recovery boiler burning black liquor fuel when being monitored by one of the Input/Loss methods through knowledge of a stoichiometric mechanism of how a heat exchanger could be leaking a tube leakage flow rate into the combustion gas path, the method for quantifying the operation comprising the steps of:

developing a mathematical model of the combustion process incorporating terms commonly associated with fossil fuel combustion and terms associated with sources of working fluid flows into the combustion gas path including tube leakage,

obtaining a set of Choice Operating Parameters,

obtaining a set of Reference Fuel Characteristics,

obtaining a fuel chemistry of the fuel being combusted by the recovery boiler using one of the Input/Loss methods, the mathematical model of the combustion process, the set of Choice Operating Parameters, and the set of Reference Fuel Characteristics, said fuel chemistry resulting in a set of fuel concentrations,

establishing a set of concentration limits for each fuel constituent based on Reference Fuel Characteristics,

testing the set of fuel concentrations against the set of concentration limits resulting in a trip mechanism indicating the stoichiometric reason how a heat exchanger leaks a tube leakage flow rate into the combustion gas path, and

reporting the trip mechanism to the operator of the recovery boiler.

24. A method for quantifying the operation of a recovery boiler burning black liquor fuel when being monitored by one of the Input/Loss methods through knowledge of a stoichiometric mechanism of how a heat exchanger could be leaking a tube leakage flow rate into the combustion gas path, the method for quantifying the operation comprising the steps of:

developing a mathematical model of the combustion process incorporating terms commonly associated with fossil fuel combustion and terms associated with sources of working fluid flows into the combustion gas path including tube leakage,

selecting a set of minimization techniques applicable to the recovery boiler burning black liquor fuel,

processing a set of routine inputs and convergence criteria to the minimization techniques,

assuming a tube leakage flow rate is zero,

selecting a set of routine Choice Operating Parameters,

determining a set of System Effect Parameters applicable to the recovery boiler burning black liquor fuel whose functionalities effect the determination of system efficiency,

determining a set of Reference System Effect Parameters applicable to the set of System Effect Parameters,

determining an objective function applicable to the recovery boiler, the set of routine Choice Operating Parameters, the set of System Effect Parameters and the set of Reference System Effect Parameters,

optimizing the set of routine Choice Operating Parameters based on the mathematical model of the combustion process, the set of minimization techniques, and the objective function such that convergence is met resulting in a set of converged Choice Operating Parameters,

determining a fuel chemistry of the fuel being combusted by the recovery boiler using one of the Input/Loss methods, the mathematical model of the combustion process, the set of converged Choice Operating Parameters, and Reference Fuel Characteristics resulting in a fuel elemental composition, a fuel ash fraction and a fuel water fraction said composition and fractions resulting in a set of fuel concentrations,

establishing a set of concentration limits for the set of fuel concentrations based on Reference Fuel Characteristics,

testing the set of fuel concentrations against the set of concentration limits resulting in a trip mechanism indicating the stoichiometric reason how a heat exchanger leaks a tube leakage flow rate into the combustion gas path, and

reporting the trip mechanism to the operator of the recovery boiler.

25. The method of claim 24, wherein the step of establishing the set of concentration limits for the set of fuel concentrations based on Reference Fuel Characteristics and the step of testing the set of fuel concentrations against the concentration limits, comprises the steps of:

determining a set of correction factors to Choice Operating Parameters using their initial and converged values, and

establishing a set of correction factor limits for the selected Choice Operating Parameters, and testing the set of correction factors against the set of correction factor limits resulting in a trip mechanism indicating the stoichiometric reason how a heat exchanger leaks a tube leakage flow rate into the combustion gas path.

26. A method for quantifying the operation of a recovery boiler burning black liquor fuel in a combustion process through knowledge of when one of its heat exchangers, whose tubes contain working fluid heated by products of combustion, has a tube leak of working fluid mixing with the products of combustion, the method for quantifying the operation comprising the steps of:

selecting a neural network technology applicable to the recovery boiler,

selecting a set of routine inputs and database for the neural network technology,

selecting a set of Choice Operating Parameters including tube leakage flow rate,

developing a mathematical model of the combustion process incorporating terms commonly associated with a combustion process and terms associated with sources of working fluid mixing with the products of combustion including tube leakage,

obtaining a set of Reference System Effect Parameters associated with the recovery boiler,

calculating a set of System Effect Parameters based on the mathematical model of the combustion process,

optimizing the set of Choice Operating Parameters including tube leakage flow rate using the neural network technology, and the set of routine inputs and database, the set of Reference System Effect Parameters and the set of System Effect Parameters, such that convergence is met resulting in a set of converged Choice Operating Parameters including a tube leakage flow rate, and

reporting the tube leakage flow rate such that corrective action may take place.

27. The method of claim 26, wherein the step of selecting the neural network technology applicable to the recovery boiler burning black liquor fuel, comprises a step of:

selecting a Neugents technology applicable to the recovery boiler burning black liquor fuel.

28. The method of claim 26, wherein the step of selecting the neural network technology applicable to the recovery boiler burning black liquor fuel, comprises a step of:

selecting a Pegasus Technology applicable to the recovery boiler burning black liquor fuel.

29. The method of claim 26, wherein the step of selecting the neural network technology applicable to the recovery boiler burning black liquor fuel, comprises a step of:

selecting a NeuCo, Inc. technology applicable to the recovery boiler burning black liquor fuel.

30. A method for quantifying the operation of a recovery boiler burning black liquor fuel when being monitored by one of the Input/Loss methods coincident with one of its heat exchangers leaking its working fluid into the combustion gas path producing a tube leakage flow, the method for quantifying the operation by identification of the leaking heat exchanger comprising the steps of:

identifying a set of heat exchangers descriptive of the recovery boiler as employed to transfer net energy flow to the working fluid from the combustion gases resulting in a set of identified heat exchangers,

obtaining a set of Operating Parameters applicable to the set of identified heat exchangers,

analyzing a set of net energy flows to the working fluid from the combustion gases based on the set of identified heat exchangers, the set of Operating Parameters and the tube leakage flow rate, each analyzed set descriptive of the recovery boiler and wherein each analyzed set the tube leakage flow rate is assigned to a different heat exchanger, resulting in an analyzed set of heat exchangers,

determining a reference key comparative parameter for the recovery boiler,

obtaining a set of key comparative parameters associated with each identified heat exchanger, applicable with the reference key comparative parameter, and based on the analyzed set of heat exchangers,

determining a set of deviations between the set of key comparative parameters and the reference key comparative parameter,

determining an identification of the leaking heat exchanger based on the set of deviations, and

reporting to the operator of the recovery boiler the identification of the leaking heat exchanger such that corrective action may take place.

31. The method of claim 30, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a fuel flow as the reference key comparative parameter for the recovery boiler.

32. The method of claim 30, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a fuel water fraction as the reference key comparative parameter for the recovery boiler.

33. The method of claim 30, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a heating value as the reference key comparative parameter for the recovery boiler.

34. The method of claim 30, wherein the step of determining the reference key comparative parameter for the recovery boiler, comprises a step of:

selecting a computed cleanliness factor for each heat exchanger as the reference key comparative parameter for the recovery boiler.

35. A method for quantifying the operation of a recovery boiler burning a fossil fuel in a combustion process through knowledge of when one of its heat exchangers, whose tubes contain working fluid heated by products of combustion, has a tube leak of working fluid mixing with the products of combustion, the method for quantifying the operation comprising the steps of:

monitoring the recovery boiler using one of the Input/Loss methods,

developing a mathematical model of the combustion process incorporating terms commonly associated with the combustion process and terms associated with sources of working fluid mixing with the products of combustion including tube leakage,

determining a tube leakage based on the mathematical model of the combustion process, and

reporting the tube leakage such that corrective action may take place.

36. The method of claim 35, wherein the step of developing a mathematical model of the combustion process comprises the steps of:

forming a hydrogen stoichiometric balance of the combustion process including terms associated with sources of working fluid mixing with the combustion products including tube leakage, and

solving the hydrogen stoichiometric balance for the tube leakage.

37. The method of claim 35, wherein the step of monitoring the recovery boiler using one of the Input/Loss methods, comprises the step of:

monitoring the recovery boiler using The Input/Loss Method.

38. The method of claim 35, wherein the step of monitoring the recovery boiler using one of the Input/Loss methods, comprises the step of:

determining a fuel chemistry based on one of the Input/Loss methods.

39. The method of claim 35, wherein the step of monitoring the recovery boiler using one of the Input/Loss methods, comprises the steps of:

determining a fuel heating value based on one of the Input/Loss methods.

40. The method of claim 35 further comprising the steps, after reporting, of:

identifying a set of heat exchangers descriptive of the recovery boiler resulting in a set of identified heat exchangers,

obtaining a set of Operating Parameters applicable to the set of identified heat exchangers resulting in a set of heat exchanger data sufficient to determine net energy flow to the working fluid from the products of combustion for each heat exchanger in the set of identified heat exchangers,

calculating a net energy flow to the working fluid of the recovery boiler as many times as there are heat exchangers in the set of identified heat exchangers, wherein each calculation of net energy flow includes all heat exchangers in the set of identified heat exchangers, wherein for each calculation of net energy flow the tube leakage is assigned to a different heat exchanger, resulting in a set of analyzed heat exchangers based on the set of heat exchanger data,

determining a set of reference key comparative parameters,

obtaining a set of key comparative parameters associated with the set of identified heat exchangers applicable with the set of reference key comparative parameters, and based on the set of analyzed heat exchangers,

determining a set of deviations between the set of key comparative parameters and the set of reference key comparative parameters,

identifying a location of the heat exchanger within the recovery boiler having the tube leak based on the set of deviations, and

reporting to the operator of the recovery boiler the location of the heat exchanger within the recovery boiler having the tube leak such that corrective action may take place.

41. A method for quantifying the operation of a recovery boiler burning a black liquor fuel in a combustion process through knowledge of when one of its heat exchangers, whose tubes contain working fluid heated by products of combustion, has a tube leak of working fluid mixing with the products of combustion, the method for quantifying the operation comprising:

determining a location of the heat exchanger within the recovery boiler with the tube leak based on the working fluid's energy flow by assigning the tube leak to different heat exchangers.

42. The method of claim 41 further comprising:

obtaining a heating value of the black liquor fuel,

obtaining a Firing Correction applicable to the recovery boiler,

obtaining a high accuracy boiler efficiency, and

determining a calculated fuel flow based on the working fluid's energy flow effected by the tube leak of working fluid, the location of the heat exchanger within the recovery boiler with the tube leak, the high accuracy boiler efficiency, the fossil fuel heating value, and the Firing Correction.

43. The method of claim 41 further comprising:

obtaining a high accuracy boiler efficiency,

obtaining a useful output produced from the recovery boiler,

determining a calculated system efficiency of the recovery boiler based on the working fluid's energy flow effected by the tube leak of working fluid, the location of the heat exchanger within the recovery boiler with the tube leak, the high accuracy boiler efficiency and the useful output produced from the recovery boiler.

44. The method of claim 42, wherein the step of obtaining the high accuracy boiler efficiency comprises:

using the black liquor fuel's calorimetric temperature, established when determining the fuel's heating value, as the thermodynamic reference energy level for an Enthalpy of Products

term, as the thermodynamic reference energy level for an Enthalpy of Reactants term, and also as the thermodynamic reference energy level for a Firing Correction term evaluated independent of a fuel flow and an effluent flow, said terms comprising the major terms of the high accuracy boiler efficiency.

45. The method of claim 43, wherein the step of obtaining the high accuracy boiler efficiency comprises:

using the black liquor fuel's calorimetric temperature, established when determining the fuel's heating value, as the thermodynamic reference energy level for an Enthalpy of Products term, as the thermodynamic reference energy level for an Enthalpy of Reactants term, and also as the thermodynamic reference energy level for a Firing Correction term evaluated independent of a fuel flow and an effluent flow, said terms comprising the major terms of the high accuracy boiler efficiency.

46. The method of claim 42 wherein the step of obtaining the heating value of the black liquor fuel comprises:

obtaining a higher heating value of the fuel,

obtaining a lower heating value of the fuel;

and wherein the step of obtaining the high accuracy boiler efficiency comprises:

obtaining a higher heating value high accuracy boiler efficiency based on the higher heating value of the fuel,

obtaining a lower heating value high accuracy boiler efficiency based on the lower heating value of the fuel;

and wherein the step of determining the calculated fuel flow comprises:

demonstrating that a computed fuel flow based on the higher heating value high accuracy boiler efficiency and a computed fuel flow based on the lower heating value high accuracy boiler efficiency are comparable.

47. A method for quantifying the operation of a recovery boiler burning black liquor fuel having a heat exchangers/combustion region producing combustion products, the method comprising the steps of:

before on-line operation, the steps of

obtaining reference fuel characteristics including at least intrinsic chemical relationships between fuel hydrogen and fuel carbon, and between fuel sodium and fuel carbon, and

developing explicit mathematical models of the combustion process involving at least stoichiometric balances; and thereafter

operating on-line, the step of operating on-line including the steps of

measuring a set of measurable operating parameters, including at least effluent concentrations of O_2 and CO_2, these measurements being made at a location downstream of the heat exchangers/combustion region of the recovery boiler,

obtaining an effluent concentration of H_2O, if reference fuel characteristics indicate fuel water is not predictable, as an obtained effluent H_2O,

obtaining an ambient concentration of O_2,

obtaining an air pre-heater leakage factor, and

calculating a complete As-Fired fuel chemistry, including fuel water and fuel inerts, as a function of the reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the ambient concentration of O_2, and the air pre-heater leakage factor.

48. The method of claim 47, wherein the step of operating on-line includes the additional step after calculating the complete As-Fired fuel chemistry, of

calculating consistent moisture-ash-free, dry and As-Fired fuel heating values as a function of the complete As-Fired fuel chemistry and the reference fuel characteristics.

49. The method of claim 48, including, after the step of calculating consistent moisture-ash-free, dry and As-Fired heating values, the additional steps of

obtaining a System Effect Parameter associated with the recovery boiler and its fuel,

completing a multidimensional minimization analysis employing the System Effect Parameter to minimize the error associated with at least one of the measured effluent CO_2, the obtained effluent H_2O, the ambient concentration of O_2 and the air pre-heater leakage factor,

calculating and applying for subsequent on-line analysis correction factors to the measured effluent CO_2, obtained effluent H_2O, the ambient concentration of O_2, and the air pre-heater leakage factor.

50. A method for quantifying the operation of a recovery boiler burning black liquor fuel in which a fossil fuel is supplied at a flow rate to a heat exchangers/combustion region and combusted to produce hot combustion gases, which heats a working fluid then exits through an exhaust stack, the method comprising the following steps:

performing an off-line operation comprising the steps of

obtaining reference fuel characteristics,

obtaining current measurements of the system's operating parameters, and

performing an on-line operation comprising the steps of

measuring the useful output of the system,

obtaining fuel data and characteristics, the step of obtaining fuel data including the step of obtaining composite fuel concentrations and composite heating value, if multiple fuels are used,

introducing fuel concentrations and heating values to a mathematical model of the recovery boiler,

obtaining routine systems operational parameters,

obtaining values of the effluents O_2, CO_2, H_2O and SO_2,

obtaining the ambient concentration of O_2,

obtaining air pre-heater leakage and dilution factors,

computing molar moisture-ash-free fractions of fuel carbon and fuel water as explicit stoichiometric solutions, dependent at least in part on the reference fuel characteristics, the effluents O_2, CO_2, H_2O and SO_2, ambient concentration of O_2, and air pre-heater leakage and dilution factors,

finding the molar moisture-ash-free fractions of fuel nitrogen, oxygen, hydrogen, sulfur, sodium, potassium and chloride,

converting the molar moisture-ash-free fuel concentrations to a molar dry base, then to a molar As-Fired wet base, and finally to As-Fired wet weight fractions, to obtain a complete and consistent computed As-Fired fuel chemistry,

computing a heating value based on a moisture-ash-free weight base, then converted to a dry base, and then to a weight-based As-Fired heating value, and

executing the mathematical model of the recovery boiler using the fuel information and the concentration of effluent O_2 to produce consistent stoichiometric values of effluent CO_2, SO_2 and H_2O values, the moles of fuel per basis moles of dry gaseous effluent, and at least the following self-consistent thermal performance parameters: As-Fired fuel flow, effluent flow, emission rates, boiler efficiency, and over-all system thermal efficiency.

51. The method of claim 50, including an additional step, after the step of executing, of

performing analysis of instrumentation errors to obtain correction factors, and, if excessive, applying the correction factors to instrumentation signals such that subsequent on-line operation produces minimum errors in fuel chemistry and heating value determinations.

52. The method of claim 51, including an additional step, after the step of performing analysis of instrumentation errors, of

adjusting operation of the system to improve its efficiency based upon the results.

53. A method for quantifying the operation of a recovery boiler burning black liquor fuel having a heat exchangers/combustion region producing combustion products, the method comprising the steps of:

before on-line operation, the steps of

obtaining a set of reference fuel characteristics, and

developing explicit mathematical models of the combustion process involving at least stoichiometric balances; and thereafter

operating on-line, the step of operating on-line including the steps of

measuring a set of measurable operating parameters, including at least effluent concentrations of O_2 and CO_2, these measurements being made at a location downstream of the heat exchangers/combustion region of the recovery boiler,

obtaining an effluent concentration of H_2O if the set of reference fuel characteristics indicates that fuel water is not predictable, as an obtained effluent H_2O,

obtaining a concentration of O_2 in the ambient air entering the recovery boiler,

obtaining an air pre-heater leakage factor,

calculating a set of fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts, as a function of the set of reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

54. The method of claim 53, wherein the step of calculating the set of fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts, includes the step of

calculating a set of moisture-ash-free fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts as a function of the set of reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

55. The method of claim 53, wherein the step of calculating the set of fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts, includes the step of

calculating a set of dry-based fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts as a function of the set of reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

56. The method of claim 53, wherein the step of operating on-line includes the additional step after calculating the complete As-Fired fuel chemistry, of

calculating an As-Fired fuel heating value as a function of the complete As-Fired fuel chemistry and the set of reference fuel characteristics.

57. The method of claim 56, including, after the step of calculating the As-Fired fuel heating value, the additional steps of

obtaining a set of System Effect Parameters associated with the recovery boiler and its fuel,

completing a multidimensional minimization analysis employing the set of System Effect Parameters to minimize the collective error associated with at least one of the measured effluent CO_2, the obtained effluent H_2O, the obtained fuel flow, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor,

obtaining and applying for subsequent on-line analysis correction factors to the measured effluent CO_2, the obtained effluent H_2O, the obtained fuel flow, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

58. The method of claim 56, wherein the set of measurable operating parameters includes effluent temperature, and wherein the method includes an additional step, after the step of calculating the As-Fired fuel heating value, of

obtaining a Firing Correction term,

calculating a high accuracy boiler efficiency as a function of the complete As-Fired fuel chemistry, effluent temperature, the effluent concentrations, the As-Fired fuel heating value and the Firing Correction term.

59. The method of claim 53, wherein the step of operating on-line includes the additional step after calculating the complete As-Fired fuel chemistry, of

calculating an As-Fired fuel heating value as a function of the complete As-Fired fuel chemistry and the set of reference fuel characteristics.

60. The method of claim 59, including, after the step of calculating the As-Fired fuel heating value, the additional steps of

obtaining a set of System Effect Parameters associated with the recovery boiler and its fuel,

completing a multidimensional minimization analysis employing the set of System Effect Parameters to minimize the collective error associated with at least one of the measured effluent CO_2, the obtained effluent H_2O, the obtained fuel flow, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor,

obtaining and applying for subsequent on-line analysis correction factors to the measured effluent CO_2, the obtained effluent H_2O, the obtained fuel flow, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

61. The method of claim 47, wherein the step of calculating the complete As-Fired fuel chemistry includes the step of

calculating explicitly a complete As-Fired fuel chemistry, including fuel water and fuel inerts, as a function of the reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

62. The method of claim 47, wherein the step of obtaining the ambient concentration of O_2 includes the step of

using a value of 20.948 percent for the ambient concentration of O_2.

63. The method of claim 47, wherein the step of obtaining the ambient concentration of O_2 includes the step of

using an average value at sea level determined by the National Aeronautics and Space Administration for the ambient concentration of O_2.

64. The method of claim 47, wherein the step of obtaining the air pre-heater leakage factor includes the step of

using a value of unity for the air pre-heater leakage factor.

65. The method of claim 53, wherein the step of calculating the set of fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts, includes the step of

calculating explicitly a set of fuel chemistry concentrations including elemental fuel constituents, fuel water and fuel inerts as a function of the set of reference fuel characteristics, explicit mathematical models of the combustion process, the set of measurable operating parameters, the obtained effluent H_2O, the concentration of O_2 in the ambient air entering the recovery boiler, and the air pre-heater leakage factor.

66. The method of claim 53, wherein the step of obtaining the concentration of O_2 in the ambient air entering the recovery boiler includes the step of

using a value of 20.948 percent for the concentration of O_2 in the ambient air entering the recovery boiler.

67. The method of claim 53, wherein the step of obtaining the concentration of O_2 in the ambient air entering the recovery boiler includes the step of

using an average value at sea level determined by the National Aeronautics and Space Administration for the concentration of O_2 in the ambient air entering the recovery boiler.

68. The method of claim 53, wherein the step of obtaining the air pre-heater leakage factor includes the step of

using a value of unity for the air pre-heater leakage factor.